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EFFECT OF CRUMB RUBBER AGGREGATES ON THE CHARACTERISTICS OF CEMENT CONCRETE AS PARTIAL REPLACEMENT

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ABSTRACT

Concrete is an outstanding structural substantial, and is regarded as beneficial for the modern civilization as well as human society. Henceforth, the manipulation of crumb rubber in concrete has been considered technically probable and this concrete is being regarded light weight concrete. Crumb rubber is produced in large sum as a waste and does not have beneficial disposal, till currently. In the present study, we have intended to study the use of crumb rubber by measurement of 5%, 6%, 7%, and 8%, in the substitution of blend of cement concrete percentage, in structural as well as non-structural associates , and also display how it is appropriate for the concrete, its uses, barriers and benefits and the way to the upcoming study. And, to decide the characteristics of concrete encompassing crumb rubber. Out of certain outcomes, we inferred that there is a reduction in mechanical properties of the concrete. Besides grounded on the outcomes of certain tests, concrete containing crumb rubber particles as combinations is still not acclaimed for structural usages due to the low compressive strength. The measured parameters of samples are, water absorption, compressive strength, splitting strength, and flexural strength. This study gives experimentations on normal strength concrete, blended with dissimilar rates of crumb rubber powder. The outcomes showed the opportunity of gaining the top rate of powder incorporation with no harm to the compressive as well as tensile strength of concrete. Results shows that 5% crumb rubber of 0.42 w/c ratio is the best mix to achieve the reduced rate of water absorption and suitable compressive strength. This kind of concrete displays the capacity for becoming a supplementary and maintainable solution for tyre rubber waste management.

KEYWORDS: Crumb Rubber; Rubberized Concrete; Mechanical Properties; Compression & Absorption of Water

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INTRODUCTION

Concrete, is generally used in the building universally, and the exhaustion of the regular resources of concrete blend is a concern to worry about. When demanding these materials, the cost of construction also increases. By making less the use of natural resources in concrete through incorporating with recycle substantial, this might help reduce the cost of construction, and thus lessen the amount of material dumped into landfill. Waste resources like recycled plastic, rice hush ash, waste glass, wood ash are instances of materials that can be used in concrete. Of numerous recycle materials that can be manipulated, disposal of vehicle tires and materials has an effect on the surroundings [1]. The world population has been concentrating on the notions of sustainability, and numerous parts associated with science and technology are proposing substitutions to regulate or minimize damages produced by the inseparable consumption of raw resources, as well as by the large volume of waste made.

The recycling of waste is a workable alternative and civil construction is an encouraging sector to engross these constituents [2]. As a resolution for this problematic issue, the debris made in creations and the waste resources

from other industries such as tires, plastics, glass as well as shoe soles could be used as masses in the conformation of concretes as well as mortars. Tire is an instance of the richness of urban trash and it is simply found in landfills, dumps, open stockpiles, roadsides as well as rivers. In addition to representing a waste, it can cause serious issues such as soil contamination, rivers pollution, besides being a shelter for disease vectors, such as dengue[3]. The chemical conformation of tire rubber is usually 20%carbon, 7% hydrogen, 1.2% zinc oxide, 1.3% sulfur, 15% iron and 5.5% other constituents[4]. The qualities of crumb rubber concrete were considerably influenced by rubber content. Ghaly as well as Cahill studied the compressive strength of concrete, with dissimilar replacement ratios of crumb rubber by volume (5%, 10% and 15%) [5]. Rubber particles have satisfactory workability, when it is manipulated to substitute total aggregate of up to 50%, but the strength is abridged correspondingly with replacement of rubber in the blend [6-7].

Even though compressive strength is condensed, concrete with rubber particles exhibit yielding as well as plastic failure rather than brittle disappointment found with normal concrete [8]. Other than that, concrete with rubber has good resistance as well as the shrinkage which is almost negligible [9]. Through microscopic inquiry, heterogeneous and hydrophoble rubber particles disturb hydration process of cement, that lead to loss in compressive strength [10]. There are latent for rubber to be used in production industry, henceforth, this study discovers the potential application of rubber particle as cement substitution in the concrete. This paper investigates the mechanical properties of concrete, containing waste crumb rubber. The rubberized concrete was produced by replacing the partial mixture with crumb rubber, at different volume ratios. Compressive strength, splitting tensile strength, and flexural strength were evaluated for concretes with different contents of crumb rubber. Absorption of water also was studied.

EXPERIMENTAL

Materials

Complex Portland cement of Grade 32.5 (regular type) with a definite gravity of 3.12, compatible to GB5/1984 [11], was manipulated as the cementations substantial as revealed in Table (1). The first setting time was ≥45 min, and the last setting time was≤ 10 hrs. The compressive strength of cement was 35.9 MPa, which contented with the design strength prerequisite. Natural river sand (medium sand) with a fineness modulus of 2.67 was approved as the acceptable aggregate. Furthermore, the particle size supply is exemplified in Table (2). Crushed gravels with a nominal maximum size were manipulated as coarse aggregates exemplified in Table (3) .The exact gravity of fine aggregate as well as coarse aggregate was 2.65 and 2.7, respectively. The water was potable-grade water in the research laboratory.

Crumb rubber together with the particle size (2–4 mm), particularly manipulated to pave a rubber runway was nominated as the substituent material, as revealed in Table (4). The bulk density was 1.15. Conforming studies designated that the concrete encompassing (2–4 mm) crumb rubber had superior properties [12].

Table 1: Physical Properties of Cement

Physical Properties	Test Results	Limits of Iraqi Specification No. 5/1984
Specific Surface Area (Blain Method) (m^2/kg)	319	≥ 230
Soundness (Le – chattier method) (mm)	0.4	< 10
Setting time (Vi cats method) - Initial setting time (hrs. min) - Final setting time (hrs. min)	1:35 2:30	$\geq 45\ min$ $\leq 10\ hrs.$
Compressive Strength - 3 days	116.1 24.5	≥ 15 ≥ 23

- 7 days		

Table 2: Grading of Fine Aggregate

Sieve Size (mm)	Cumulative Passing %	Limits of Iraqi Specification No. No. 45/1984
5	100	-
2.36	82	65 – 100
1.18	67	45 – 100
0.6	49	25 – 80
0.3	17	5 – 48
0.15	3	-

Fineness modulus= 2.67

Table 3: Grading of Coarse Aggregate

Sieve Size (mm)	Cumulative Passing %	Limits of Iraqi Specification No. No.45/1984
37	100	100
19	99	75 – 100
13.2	67	-
9.5	32	30 – 600
4.75	0.84	0 – 10
2.36	0.008	-

Table 4: Characteristics of Crumb Rubber Used in this Study

Characteristics	
BULK density	1.15
Sulfur content,	% 1.74
Polymer base, N/S/B	60/20/20
Composition	
Rubber, %	65.82
Carbon black, %	28.77
Ash, %	5.41
Total, %	100.00

MIXTURE PROPORTION

This study comprised of one plain concrete as the regulator and (5) crumb rubber concretes. The concretes were premeditated at a continuous water cement ratio of 0.42. Crumb rubber was manipulated as the constituents for an equivalent part of concrete blend. Bearing in mind the diverse definite gravities of crumb rubber as well as inorganic materials, the substituent's with crumb rubber was founded on the volume other than weight [13-14]. To replace the levels of crumb rubber, it was diverted from 5% to 8% by volume, for the concrete blend.

Table 5: Mixture Proportions of Crumb Rubber Concrete

Weight Per Cubic Meter Kg/m3						
Mix	**Rubber Content %**	**Water Content**	**Cement**	**Fine Aggregate**	**Coarse Aggregate**	**Total Mixture**
CRD	0	180	430	395	1197	2202
	5					**2197**
	6					2196
	7					2195
	8					2194

Figure 1: Crumb Rubber Concrete

PREPARATION OF SPECIMENS

Blending the mixture was showed by a power-driven turning pan mixer. To attain a more homogenous spreading of rubber particles in the blend with less entangled air, the pretreatment of crumb rubber was accomplished for 5 min, before being supplementary into the blender. The mixing process was happening with 2 min of premixing of cement, masses as well as crumb rubber. After that, a further 2 min of mingling were showed after the addition of the water. After mixing, the mixture was poured into the molds with three layers. A vibration for five seconds was performed after rodding 25 times for each layer .All specimens were removed from the molds after 7, 24 h and cured in the conditions of 20 ± 3 ^{O}C and 95% relative humidity. Prismy specimens (100 mm ×200 mm) were used to test the compressive strength. Cube specimens (100×200mm)were produced for measuring compressive strength, splitting tensile strength and flexural strength.

TEST METHODS

Mechanical Properties

Compressive Strength Test

The compressive strength test was made according to B. S.1881: part 116 [15] using 100 mm cubes. The compressive strength cubes were tested using a standard testing machine with capacity of 2000 kN. The loading was applied at a rate of 15 MPa per minute. The average of three specimens was recorded for each testing age.

Splitting Tensile Strength Test

The splitting tensile strength test was carried out in accordance with ASTM C496-96 [16]. Cylinders of (100×200) mm diameter were used, and tests were performed using a standard testing machine at a rate of 1.5 MPa per minute. The average of three cylinders was taken at each test. The splitting tensile strength is given by the following equation(1):

$$f_t = \frac{2P}{\pi d\, L} \tag{1}$$

Where

f_t = splitting tensile strength, (MPa)

P = maximum applied load, (N)

d = diameter of specimen, (mm)

L = length of the specimen, (mm)

Flexural Strength Test

This test was carried out on (100×100×500) mm prism specimens, in accordance with B. S.1881: part 118 [17], using flexural strength test machine of 30000 kg capacity at a rate of 1.6 MPa per minute The maximum tensile stress occurs within the central bottom of the beam for all specimens, therefore the modulus of rupture was calculated using the following equation (2):

$$f_r = \frac{P\,L}{b\,d^2} \qquad (2)$$

where

f_r = modulus of rupture, (MPa)

p = maximum applied load, (N)

L = span length, (mm)

d = depth of the specimen, (mm)

b = width of the specimen, (mm)

Absorption Test

This test was carried out according to ASTM C642-97 [18] on 100 mm cube specimens. Firstly, the specimens were weighed, and then dried in oven at temperature of 100-110˚C for a period of 24 hours. After that, they were removed from the oven and allowed to cool in dry air to a temperature of 20- 25˚C and reweighed. The above procedure was repeated until the difference between two successive weights did not exceed 0.5 %, and the final weights were considered as oven dried weights .Then, the specimens were immersed in water at a temperature about 21˚C for 48 hours. After that, the surfaces of specimens were dried with cloth and weighed .This procedure was repeated until the difference between two successive weights of surface dried specimens at intervals of 24 hours shows an increase in weights less than 0.5 % of the heavier weights. The final weights were considered surface dried weights after immersion.

Absorption of each specimen is calculated, as the increase in weight resulting from immersion is expressed as a percentage of the weight of the dry specimen.

$$\textbf{Absorption}\% = B\text{-}A\,/A\ {*}100 \qquad (3)$$

Where:

A= The weight of the dry specimen (gm)

B= The weight of the immersed specimen (gm)

RESULTS AND DISCUSSIONS

The mechanical properties and durability of concrete were significantly affected by introducing crumb rubber into concrete. In this paper, the variation of properties in concrete with the changing of rubber content was investigated. Additionally, the effect of modifiers was evaluated.

MECHANICAL PROPERTIES

The mechanical properties of crumb rubber concrete were tested and are listed in Tables (6,7,8) .The compressive strength of crumb rubber concrete cured for 7 and 28 days was lower than that of the control concrete (34.76 MPa). It was also observed that the compressive strength of C. R. C (crumb rubber replacing concrete mixture) reduced from15.3 MPa down to10.9 MPa with increasing rubber content from 5% to 8%. The minimum compressive strength at the 8% replacement level satisfied the strength requirement of CRC concrete. When 5% of the total mixture was replaced, the compressive strength had an acceptable value of 15.3 Mpa. However, a reduction (43%) was observed at the 8% replacement level. Compared to the replacement of mixture, replacing the mixture concrete with crumb rubber led to a marginal decline of the compressive strength. The splitting tensile strength of crumb rubber concrete cured at 7 and 28 days was measured, as shown in Table(7). It was observed that the splitting tensile strength decreased with the increase in the volume percentage of crumb rubber. Similar to compressive strength, this was because replacing mixture with crumb rubber reduces the mass of cement. The Splitting Tensile Strength was weakened due to loss bonding material. Moreover, the ratio of the reduction in the splitting tensile strength was lower than the compressive strength, which was owed to the rubber providing a better bridge between propagated cracks and limiting their development [19]. When 8% was replaced by crumb rubber, the splitting tensile strength decreased by1.0%, whereas compressive strength decreased by 10.9%.

The reduction in compressive strength is due to the increasing of the percentage content of crumb rubber. The flexural strength represented the deformation capacity of concrete. It was observed that the flexural strength for rubberized concrete decreased with the increase of the replacement level of crumb rubber. In the case of CRC, the flexural strength was reduced from 5.2MPa down to 2.3MPa with the increasing rubber replacement level from 5% to 8%. The reduction in the flexural strength was higher when the mixture was replaced. Rubber particles had a low modulus of elasticity with respect to mineral aggregate, which resulted in the weak resistance to external applied load. Due to this, crumb rubber particles had a low modulus of elasticity with respect to mineral aggregate, which resulted in the weak resistance to external applied load. Due to this, crumb rubber concrete exhibited an obvious deformation performance and better toughness .There are many reasons accounting for the lower strength of crumb rubber concrete [20]. Firstly, the adhesion of rubber particles and cement paste is weaker than the mineral aggregate .Secondly, the distribution of rubber particles in the concrete mixture is non-homogenous, due to the lower specific gravity compared to other materials. Thirdly, the hydrophobic nature of rubber particles takes bubbles into the concrete mixture and increases the air content. Due to the above reasons, the mechanical strength is reduced when the crumb rubber is introduced into the concrete.

Table 6: Compressive Strength of Mixes

Type of Mix	w/c	Compressive Strength	
		7 Days	28 Days
R	0.42	20.9	25.3
5 % C.R.C	0.42	12.3	15.3
6 % C.R.C	0.42	10.2	10.6
7 % C.R.C	0.42	10.0	12.8
8 % C.R.C	0.42	8.5	10.9

Table 7: Splitting Tensile Strength of Mixes

Type of Mix	w/c	Splitting Tensile Strength	
		7 Days	28 Days
R	0.42	2.1	2.7
5 % C.R.C	0.42	1.3	1.4
6 % C.R.C	0.42	1.1	1.2
7 % C.R.C	0.42	1.1	1.3
8 % C.R.C	0.42	0.9	1.0

Table 8: Flexural Strength Test of Mixes

Type of Mix	w/c	Flexural Strength	
		7 Days	28 Days
R	0.42	2.8	5.2
5 % C.R.C	0.42	2.5	3.1
6 % C.R.C	0.42	2.6	3.2
7 % C.R.C	0.42	2.3	2.8
8 % C.R.C	0.42	2.1	2.3

Figure 2: Flexural TEST

Figure 3: Compressive TEST

ABSORPTION OF WATER

Table (9) shows the same trend of water absorption rate for all 5 mixes. It shows that 8% CRC mix had the highest absorption rate compares to other mortar mixes. The other mixes had almost equal water absorption rate. 5-6% CRC mix had almost constant water absorption rate for the whole 28day test. Overall results show that control mixes had highest water absorption percentile compare to the other mixes, particularly at 7and 28, for 0.42 w/c ratio the more mixture replaced with CRC the increase in the rate of water absorption.

Table 9: Absorption Test of Mixes

Type of Mix	w/c	Absorption of Water %	
		7 Days	28 Days
R	0.42	1.0	1.0
5 % C.R.C	0.42	1.0	1.0
6 % C.R.C	0.42	1.0	1.0
7 % C.R.C	0.42	1.5	1.5
8 % C.R.C	0.42	2.0	2.0

CONCLUSIONS

In this paper, crumb rubber concretes with different replacement forms and replacement levels were produced. The effect of the volume content of crumb rubber and pretreatment methods on the performances of concrete was investigated. The following conclusions have been obtained. Adding crumb rubber into concrete resulted in a significant decrease of the mechanical properties. (1) The effect caused by replacing the mixture with crumb rubber was higher. (2) Compressive strength, splitting tensile strength and flexural strength were reduced with the increasing percentage content of crumb rubber. A 5% replacement of the total mixture with crumb rubber met the safety strength requirements of concrete.(3) The negative effect of crumb rubber on mechanical strength could be minimized and avoided by pretreatment of the crumb rubber, using modifiers. The 5-6 % water absorptions of CRC 0.42 w/c ratio at 7 and 28 days were much lower, when compared to the control.

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